

WolfSSL

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Insert Date

Contents

1	SSL Protocol	1
1.1	Introduction	1
1.2	SSL Handshake	3
2	Wolf SSL	6
3	Test case	9
3.1	Client/Server provided by WolSSL	9
3.2	EchoClient/EchoServer provided by WolfSSL	11

Abstract

Explanation of this article. Must be a synthesis

Chapter 1

SSL Protocol

1.1 Introduction

The SSL protocol is a client/server protocol that provides the following basic security services to the communicating peers:

- Authentication (both peer entity and data origin authentication) services
- Connection confidentiality services
- Connection integrity services

The SSL protocol is sockets-oriented, meaning that all or none of the data that is sent to or received from a network connection is cryptographically protected in exactly the same way. It can be best viewed as an intermediate layer between the transport and the application layer that serves two purposes:

- Establish a secure connection between the communicating peers
- Use this connection to securely transmit higher-layer protocol data from the sender to the receiver. It therefore fragments the data in pieces called fragments; each fragment is optionally compressed, authenticated, encrypted, prepended with a header, and transmitted to the receiver. Each data fragment prepared this way is sent in a distinct SSL record.

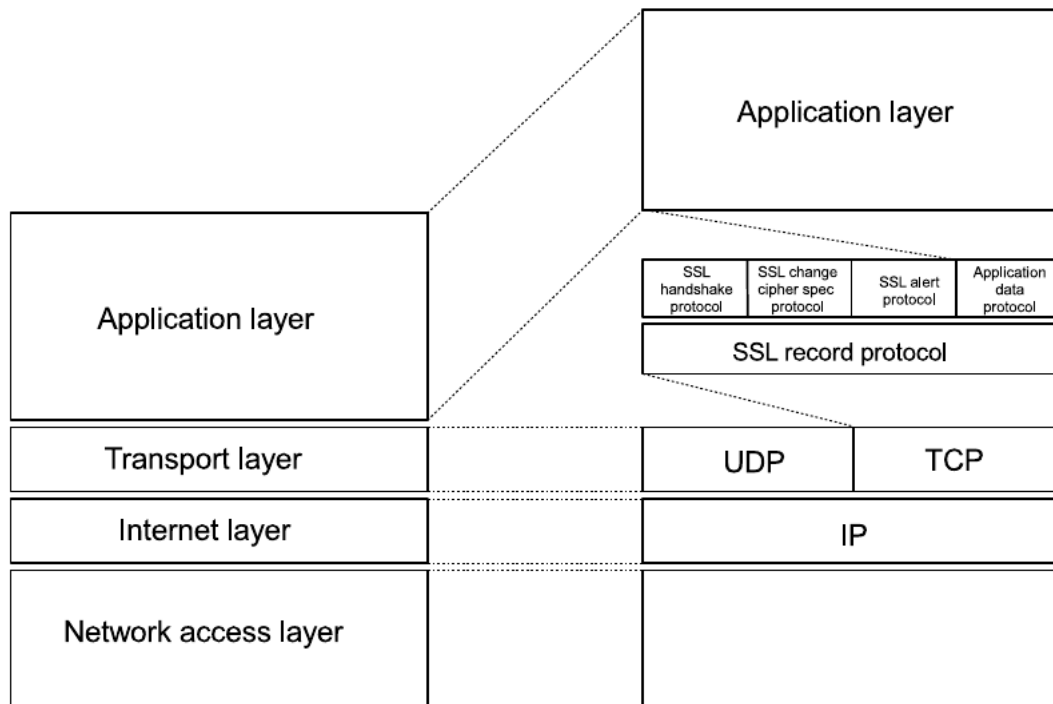


Figure 1.1: The SSL with its (sub)layer and (sub)protocols

The SSL consists of two sublayers and a few subprotocols:

- The lower sublayer is stacked on top of some connection-oriented and reliable transport layer protocol. This layer basically comprises the SSL record protocol that is used for the encapsulation of the higher-layer protocol data.
- The higher sublayer is stacked on top of the SSL record protocol and comprises four subprotocols.
 - The *SSL handshake protocol* is the core subprotocol of SSL. It is used for establishment of a secure connection. It allows the communicating peers to authenticate each other and to negotiate a cipher suite and a compression method.
 - The *SSL change cipher spec protocol* is used to put the parameters, set by the SSL handshake protocol in place and make them effective.
 - The *SSL alert protocol* allows the communicating peers to signal indicators of potential problems and send respective alert messages to each other.

- The *SSL application data protocol* is used for the secure transmission of application data.

In spite of the fact that SSL consists of several subprotocols, we use the term *SSL protocol* to refer to all of them simultaneously.

1.2 SSL Handshake

The SSL handshake protocol is layered on top of the SSL record protocol. It allows a client and server to authenticate each other and to negotiate issues like cipher suites and compression methods.

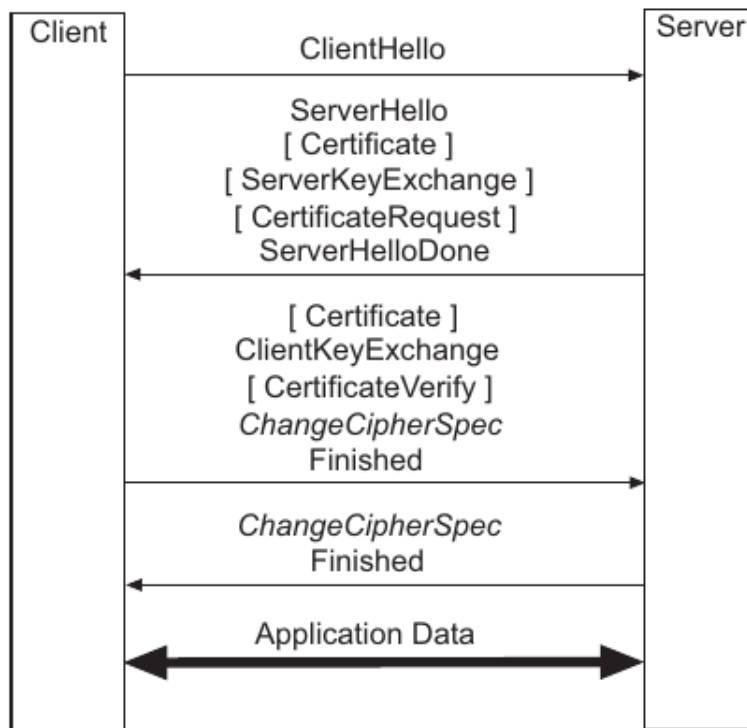


Figure 1.2: The SSL handshake protocol

The SSL handshake protocol comprises four sets of messages:

- The first flight comprises a single *ClientHello* message that is sent from the client to the server.

- The second flight comprises two messages that are sent back from the server to the client:
 1. *ServerHello* message is sent in response to the *ClientHello* message
 2. (optional) If the server is to authenticate itself, it may send a *Certificate* message to the client.
 3. (optional) Under some circumstances, the server may send a *ServerKeyExchange* message to the client.
 4. (optional) If the server requires the client to authenticate itself with a public key certificate, then it may send a *CertificateRequest* message to the client.
 5. Finally, server send a *ServerHelloDone* message to the client.
- The third flight comprises three to five messages that are again sent from the client to the server:
 1. (optional) If the server has sent a *CertificateRequest* message, then the client sends a *Certificate* message to the server.
 2. In the main step of the protocol, the client sends a *ClientKeyExchange* message to the server.
 3. (optional) If the client has sent a certificate to the server, then it must also send a *CertificateVerify* message to the server. This message is digitally signed with the private key that corresponds to the client certificate's public key.
 4. The client sends a *ChangeCipherSpec* message to the server (using the SSL change cipher spec protocol) and copies its pending write state into the current write state.
 5. The client sends a *Finished* message to the server. As mentioned above, this is the first message that is cryptographically protected under the new cipher spec.
- The fourth flight comprises two messages that are sent from the server back to the client:
 1. The server sends another *ChangeCipherSpec* message to the client and copies its pending write state into the current write state.
 2. Finally, the server send a *Finished* message to the client. Again, this message is cryptographically protected under the new cipher spec.

At this point in time, the SSL handshake is complete and the client and server may start exchanging application-layer data.

Chapter 2

Wolf SSL

The wolfSSL embedded SSL library is a lightweight SSL/TLS library written in ANSI C and targeted for embedded, RTOS, and resource-constrained environments - primarily because of its small size, speed, and feature set.

It's free and it has an excellent cross platform support.

WolfSSL supports standards up to the current TLS 1.3 and DTLS 1.2 levels, is up to 20 times smaller than OpenSSL and it's powered by the colfCrypt library.

This library is built for maximum portability and supports the C programming language as a primary interface. It also supports several other host languages, including Java (wolfSSL JNI), C# (wolfSSL C#), Python, and PHP and Perl.

To improve performance it supports hardware cryptography and acceleration on several platforms.

In the following list you can see some of WolfSSI's features:

- Runtime memory usage between 1-36 kB
- OpenSSL compatibility layer
- Hash Functions:
 - MD2
 - MD4
 - MD5
 - SHA-1
 - SHA-224
 - SHA-256
 - SHA-384
 - SHA-512
 - BLAKE2b
 - RIPEMD-160
 - Poly1305
- Mutual authentication support (client/server)

- SSL Sniffer (SSL Inspection) Support
- IPv4 and IPv6 support

The operating systems supported are:

- | | | |
|--------------------|---|---------------------------|
| 1. Win32/64 | 17. Android | 31. ARC MQX |
| 2. Linux | 18. Nintendo Wii and Gamecube through DevKitPro | 32. TI - RTOS |
| 3. Mac OS X | | 33. uTasker |
| 4. Solaris | 19. QNX | 34. embOS |
| 5. ThreadX | 20. MontaVista | 35. INtime |
| 6. VxWorks | 21. NonStop | 36. Mbed |
| 7. FreeBSD | 22. TRON / ITRON / ITRON | 37. uT - Kernel |
| 8. NetBSD | 23. Micrium C / OS - III | 38. RIOT |
| 9. OpenBSD | | 39. CMSIS -RTOS |
| 10. embedded Linux | 24. FreeRTOS | 40. FROSTED |
| 11. Yocto Linux | 25. SafeRTOS | 41. Green Hills INTEGRITY |
| 12. OpenEmbedded | 26. NXP / Freescale MQX | 42. Keil RTX |
| 13. WinCE | 27. Nucleus | 43. TOPPERS |
| 14. Haiku | 28. TinyOS | 44. PetaLinux |
| 15. OpenWRT | 29. HP / UX | 45. Apache Mynewt |
| 16. iPhone(iOS) | 30. AIX | 46. PikeOS |

Chapter 3

Test case

3.1 Client/Server provided by WolSSL

```
server@server:~/Documents/information_system_security/wolfSSL/wolfssl/examples/server$ ./server -b
SSL version is TLSv1.2
SSL cipher suite is TLS_ECDHE_RSA_WITH_AES_256_GCM_SHA384
SSL curve name is SECP256R1
Client message: hello wolfssl!
server@server:~/Documents/information_system_security/wolfSSL/wolfssl/examples/server$
```

Figure 3.1: Server SSL

```
luca@luca:~/Documents/information_system_security/wolfSSL/wolfssl/examples/client$ ./client -h 192.168.0.254
SSL version is TLSv1.2
SSL cipher suite is TLS_ECDHE_RSA_WITH_AES_256_GCM_SHA384
SSL curve name is SECP256R1
I hear you fa shizzle!
luca@luca:~/Documents/information_system_security/wolfSSL/wolfssl/examples/client$
```

Figure 3.2: Client SSL

tcp.port == 11111 && ip.addr == 192.168.0.254 && ssl					
No.	Time	Source	Destination	Protocol	Length Info
287	51.105686952	192.168.0.47	192.168.0.254	TLSv1.2	222 Client Hello
289	51.106236413	192.168.0.254	192.168.0.47	TLSv1.2	161 Server Hello
291	51.107010717	192.168.0.254	192.168.0.47	TLSv1.2	2468 Certificate
293	51.165325915	192.168.0.254	192.168.0.47	TLSv1.2	404 Server Key Exchange
295	51.165422054	192.168.0.254	192.168.0.47	TLSv1.2	98 Certificate Request, Server Hello Done
297	51.165925679	192.168.0.47	192.168.0.254	TLSv1.2	1311 Certificate
299	51.174939731	192.168.0.47	192.168.0.254	TLSv1.2	141 Client Key Exchange
301	51.189231968	192.168.0.47	192.168.0.254	TLSv1.2	335 Certificate Verify
302	51.189325871	192.168.0.47	192.168.0.254	TLSv1.2	117 Change Cipher Spec, Encrypted Handshake Message
305	51.193208227	192.168.0.254	192.168.0.47	TLSv1.2	72 Change Cipher Spec
307	51.193262294	192.168.0.254	192.168.0.47	TLSv1.2	111 Encrypted Handshake Message
311	51.193516103	192.168.0.47	192.168.0.254	TLSv1.2	109 Application Data
315	51.194124325	192.168.0.254	192.168.0.47	TLSv1.2	118 Application Data
319	51.194168545	192.168.0.254	192.168.0.47	TLSv1.2	97 Encrypted Alert
320	51.194290399	192.168.0.47	192.168.0.254	TLSv1.2	97 Encrypted Alert

▶ Frame 287: 222 bytes on wire (1776 bits), 222 bytes captured (1776 bits) on interface 0
▶ Ethernet II, Src: Dell_66:c2:8f (a4:4c:c8:66:c2:8f), Dst: AsustekC_5a:f2:0b (00:1d:60:5a:f2:0b)
▶ Internet Protocol Version 4, Src: 192.168.0.47, Dst: 192.168.0.254
▶ Transmission Control Protocol, Src Port: 41904, Dst Port: 11111, Seq: 1, Ack: 1, Len: 156
▶ Secure Sockets Layer

Figure 3.3: All SSL packets sent

3.2 EchoClient/EchoServer provided by WolfSSL

```
luca@luca:~/Documents/information_system_security/wolfSSL/wolfssl/examples/echoserver$ ./echoserver
Hi Server, I'm echoClient!
client sent quit command: shutting down!
luca@luca:~/Documents/information_system_security/wolfSSL/wolfssl/examples/echoserver$
```

Figure 3.4: EchoServer SSL

```
luca@luca:~/Documents/information_system_security/wolfSSL/wolfssl/examples/echoclient$ ./echoclient
Hi Server, I'm echoClient!
Hi Server, I'm echoClient!
quit
sending server shutdown command: quit!
luca@luca:~/Documents/information_system_security/wolfSSL/wolfssl/examples/echoclient$
```

Figure 3.5: EchoClient SSL

ssl					
No.	Time	Source	Destination	Protocol	Length Info
4	0.000056186	127.0.0.1	127.0.0.1	TLSv1.2	222 Client Hello
6	0.000147786	127.0.0.1	127.0.0.1	TLSv1.2	161 Server Hello
8	0.000189939	127.0.0.1	127.0.0.1	TLSv1.2	933 Certificate
10	0.002556695	127.0.0.1	127.0.0.1	TLSv1.2	219 Server Key Exchange
12	0.002565669	127.0.0.1	127.0.0.1	TLSv1.2	75 Server Hello Done
14	0.005584226	127.0.0.1	127.0.0.1	TLSv1.2	141 Client Key Exchange
16	0.005624458	127.0.0.1	127.0.0.1	TLSv1.2	72 Change Cipher Spec
18	0.005649888	127.0.0.1	127.0.0.1	TLSv1.2	111 Encrypted Handshake Message
20	0.006849431	127.0.0.1	127.0.0.1	TLSv1.2	72 Change Cipher Spec
22	0.006879403	127.0.0.1	127.0.0.1	TLSv1.2	111 Encrypted Handshake Message
24	20.750500681	127.0.0.1	127.0.0.1	TLSv1.2	122 Application Data
26	20.750705479	127.0.0.1	127.0.0.1	TLSv1.2	122 Application Data
28	26.744191080	127.0.0.1	127.0.0.1	TLSv1.2	100 Application Data
30	26.744218051	127.0.0.1	127.0.0.1	TLSv1.2	97 Encrypted Alert
33	26.744270747	127.0.0.1	127.0.0.1	TLSv1.2	97 Encrypted Alert

<ul style="list-style-type: none"> Transmission Control Protocol, Src Port: 55864, Dst Port: 11111, Seq: 1, Ack: 1, Len: 156 Secure Sockets Layer <ul style="list-style-type: none"> TLSv1.2 Record Layer: Handshake Protocol: Client Hello <ul style="list-style-type: none"> Content Type: Handshake (22) Version: TLS 1.2 (0x0303) Length: 151 Handshake Protocol: Client Hello <ul style="list-style-type: none"> Handshake Type: Client Hello (1) Length: 147 Version: TLS 1.2 (0x0303) Random: a1baabf21e069b1336cc31bf867416f6ef906f7eec015dbc... Session ID Length: 0 Cipher Suites Length: 48
--

Figure 3.6: All SSL packets sent